Proposed Research Plan: Ph.D Programme

Modelling and Order Reduction of Electrical Power system components in stabilities studies using Matlab/Simulink model

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A substantial portion of power system load is made of large three-phase induction machines. Transient behaviour of these machines plays a significant role in behaviour of overall system. Thus, modelling of induction machine is an integral part of some power system transient studies. It is well known that three phase induction motor is a work-horse in the area of application of motors. The induction motor drives the load having various types of torque-speed characteristics. Its detailed transient analysis has become a matter of research since a early days. The analysis takes a detailed form only when its modeling becomes perfect to a greater accuracy. When the stator eddy current path is taken into account, the uniform air-gap theory in phase model analysis becomes inefficient to take care of transients. This drawback necessitates the introduction of analysis of the machine in d-q axis frame. Thus a pin-pointed model using suitable transformation theory has been established. A full order model is appropriate when all the flux-transients are taken into accounts. In practice, some flux-transient can be ignored due to the quasi-stationary nature of the variable concerned. This philosophy leads to the formation of reduced order model. This paper takes the above matter as a main point of research. The author uses the philosophy of the speed-build up of single cage induction machine finds the speed versus time profile for various types of load condition.

As induction motor having double cage type of rotor are also of greater importance in various applications, its modelling in d-q frame in full order and in reduced order have been developed and subsequently analysed. The method of analysis of double cage type of machine is same as the single cage type of motor.

For both type of machine, the author find the speed verses time, electromagnetic torque verses time, stator and rotor flux verses time and current verses time profile for different types of loads The established fact of lessor computation time in reduced order model will be verified and improvement in accuracy is to be observed.

Further, In proposed work, modelling of various power system components such as excitation system, speed governing systems, steam turbine ,hydro turbines and typical valve characteristics is to be developed for the purpose of power system transient stability study. First of all mathematical modelling is to be developed for assessment of desired performance requirements in designing and coordination of supplementary control and protective circuits for system stability studies related to the planning and operation of power systems. The extent of details in a model depends on the purpose of the study. Simulink is advanced software by MathWorks Inc., Which is increasingly being used as a basic building blocks in many areas of research.In this work, I will take single machine infinite bus and multi machine systems examples of power system to demonstrate the features and and scope of simulink model for transient stability analysis.

A considerable amount of research works on order reduction of large scale dynamic systems and induction machine have been done since early 70s. The companion paper by Rodriguez et. al represents the isolated operation of a a group of induction motor load using reduced order model. This paper gives emphasis on the fact that when the induction machine is isolated, the open circuit terminal voltages vary at a frequency determined by the speed of the rotor. During isolated operation, this paper assumes that rotor speed is a function of the load torque and of the inertia of the machine and isolated load because electromagnetic torque is zero due to stator currents being zero. It physically reveals that this assumption will be more valid only when a machine with larger moment of inertia is considered otherwise speed will drop to zero value approximately at the same instant of isolation.

The work by Skvarenina et. al discusses the accuracy of a reduced order model of induction machine in power system dynamic stability assessment. This paper concludes that accuracy of reduced order linearised model increases as horsepower rating increases for typical machine. Moreover, when used in a power system configuration, the added reactance of the transmission lines and transformers can improve the accuracy of the reduced order model. But physically the nature of the torque like frictional torque, fan-type loading etc. may affect the accuracy of the linearised model and this aspect has not been taken by the paper into account.

The companion papers by P.W.Saur & M.A. Pai represent the reduced order modeling of interconnected multimachine power systems using time-scale decomposition. This paper gives emphasis on the fact that the analysis of interconnected multi-machine power system involves a

wide spectrum of time-scale phenomenon .It is this property which makes power system dynamics an excellent candidate for time-scale decomposition and aggregation. The use of singular perturbation has already been shown to be a valuable technique for exploiting the natural time scale properties.

Now the paper by Gill. G. Richards represents the reduced order model for an induction motor during bus transfer. This paper also gives emphasis on the fact the reduced order model may perform in accuracy during a bus transfer, when groups of induction machines and possibly static loads are isolated form the power source momentarily only and then reconnected both assumption for order reduction are violated the prevailing terminal voltage voltage frequency gradually falls from the synchronously frequency as the motor group slows during the disconnect period , causing slip frequency voltage variation on the synchronous reference time.

The companion paper by S. Ertem & Y. Baghzouz represents a variable order model of induction machines. This paper gives emphasis on the transient performance of electrical machine due to application of digital computer application to large and complicated model of electromechanical system.

Now the paper by N.A Khalil & Iris U. Bavan represent the reduced order model for double cage induction motors. It gives emphasis on the machine model has been developed for a double cage induction machine, the resulting models, however, can be applied with some degree of approximation to induction machine with deep bar rotor as well since an equivalent double cage can be found which provides the machine with an admittance locus closely fitting that of a deep-bar induction machine .

The above researchers have investigated the problem regarding modeling of induction machine in reduced order form for particular applications. Some of them considered only single cage induction machine. Furthermore it has been observed from literature review that analysis involving consideration of different types of loads is absent. The present work does the modeling and analysis of single cage and double cage machine simultaneously such that a comparative discussion can be made about the convergence criteria of the numerical for both type of induction machine. The author also approaches to consider the effect of different type of load, the speed build up is not so smooth compare to other types of load. The solutions of non-linear differential equation involving flux-linkages as the variables both in the full order model and reduced order model have been obtained alter a definite thought process. Obviously the thought process is based on the physical phenomenon of the speed-build up of induction machine, which

mathematically turns-out to be an interaction of the torque-dynamic equation with the flux-linkage equation. Thus an iterative algorithm is set-up.

The modeling and analysis of double cage machine gives an insight into the flux v/s time profiles of the inner and outer rotor cage. This insight obviously will be helpful to a designer who wants to optimize the inner and outer cage winding parameters. The detailed analysis of double cage machine also gives clear vision that it the eddy current paths of stator of single cage induction machine are taken into account then what will be resulting model and subsequent analysis.

The standard method of solving the full order and reduced order model equation is based on the Runge-Kutta fourth order method which also has been used by the author. But it is also pointed-out in the work that it same one even doesn't bother about any particular numerical methodology like Runge-Kutta method, he can straight-forward discritise the flux-linkage and torque- dynamic equation using time as a descritisation variable. This method of discritisation is totally based on the physical thought process of the problem. However so far numerical accuracy are concerned this method is not so sufficient.

Objective of the Research

The objective is to obtain reduced order models, which approximate the response of original system as closely as possible depending on the application. The proposed techniques will be applied to the models of different existing systems. After obtaining the reduced order model, the efforts will be made to design controller for the same. Further, modelling of various power system components like excitation system, speed governing systems, steam turbine ,hydro turbines will be developed for the purpose of power system transient stability study and performance parameters will be obtained using simulink model depending upon the nature of applications.

Research Plan

- To develop the full order model and reduced order model of the single cage induction machine by technique (singular perturbation method) i.e. neglecting the stator flux transient.
- To develop the full order model and reduced order model for the double cage induction machine by technique, i.e. neglecting the faster transient component.
- To develop the full order model and reduced order model for the single cage/double cage induction machine by neglecting leakage inductances.
- To simulate the above modeling for supply voltage disturbances and load torque disturbances such as no load torque, fixed load torque, frictional loading and fan-type loading.
- To study different performance characteristics for different supply voltage and torque load.
- To design controllers with reduced order systems obtained using the new proposed methods. Results will be compared with similar existing techniques.
- To develop the model of Power system components in Transient stability studies using Matlab/simulink..

2.4 Methodology

- Reduced order model applied to normal three phase induction machine of single cage design allows neglecting the stator flux transient. This assumption makes the d/dt i.e. P terms reduced in comparison to full order model hence the resulting matrixes of flux-linkage equation will be simpler & computational time will be less because algebraic manipulation help this method.
- Application to Reduced order model to normal three phase induction machine for double cage design also allows reducing the d/dt terms. It has been observed the

rotor model of double cage machine that the outer cage has material of larger resistivity. This feature

- needs to the generally of faster component of transient flux linkages in the rotor model. This can be treated as the d/dt term is neglected. In addition to normal assumption of neglecting stator flux-transient, above said points comes as an extra advantages thus in the case of double cage machine also resulting matrixes are simpler and computational time will be less.
- As a general case under transient condition if eddy current path in the stator and rotor of induction machine are taken into account, they can be treated as short-circuited coil placed on d-q axes as per conveniently. This equation becomes too much tedious for solution of flux-linkages or current or speeds on the function of time.
- The theory of neglecting stator transient has been observed to be equally valid when some one considered the d-q flux linkages equation of 3 phase salient pole synchronous machine therefore here also the advantages of model order reduction is achieved.

For practical purposes to predict the speed of certain instant, these errors are of negligible importance. It has been also experience in practical field that for prediction of current or speed or torque, the accuracy of model (in form of rigorous size) is not very important, because that accuracy has little importance on reduced prediction data

It is relevant to note that model order reduction is possible only when some body model the machine in the form of d-q machines.